US Climate Modeling Summit 2020 Report

July 24, 2020

Summary

The 6th US Climate Modeling Summit (USCMS) was held virtually because of COVID-19-related restrictions. The summit consisted of a series of four weekly webinars in April 2020 for the Global Model Cloud-Aerosol Research (GM-CAR) workshop and a two-day virtual summit June 30-July 1, 2020. The workshop involved aerosol and cloud experts from U.S. modeling centers and the broader community. The USCMS, involving core members (see Appendix C) and IGIM managers, was an opportunity for high level modeling discussions to enhance coordination and collaborations. The second part of the meeting was dedicated to the progress made at centers for the Coupled Model Intercomparison Project (Phase 6) (CMIP6) and other recent updates and discussions on coordination to tackle relevant issues. The meeting concluded with planning coordinated activities for the upcoming year, including the 7th USCMS.

Background on US Climate Modeling Summit and Workshop

To improve the coordination and communication of national climate modeling goals and objectives, USGCRP's Interagency Group on Integrative Modeling (IGIM) has been convening an annual U.S. Climate Modeling Summit since 2015. The Summit brings together representatives from the U.S. "CMIP-class" climate model development centers and from operational climate and weather prediction programs. Specifically, two representatives—one lead and one additional delegate—from each of the following groups are invited to participate in the Summit: Geophysical Fluid Dynamics Laboratory (GFDL CM/ESM); Goddard Institute for Space Studies (GISS ModelE); Global Modeling and Assimilation Office (GMAO GEOS-5); NCAR Community Earth System Model (CESM); NWS/NCEP (GFS); and DOE Energy Exascale Earth System Model (E3SM) (Appendix C).

As envisioned by the IGIM, the high-level USCMS objectives include:
1. Developing a shared understanding of modeling groups' directions and implementation strategies,
2. Identifying opportunities for enhanced coordination and synergy among modeling groups,
3. Identifying outreach opportunities to user communities

Starting in 2017, a topical workshop has also been organized under the auspices of the USCMS and in conjunction with the annual meeting. This workshop serves the purpose to have focused technical communications on a high priority modeling topic identified by the USCMS together with the IGIM, and includes invitees from the broader community.

Summary of activities since the previous USCMS

Since the 5th USCMS in April 2019, a number of collaborative projects were initiated. Firstly, based on the workshop on the representation of modes of variability in the models, an IGIM-funded study worked on a thorough exploration of the improvements in model skill across a suite of modes. This study resulted in a published paper (Orbe et al., 2020) which showed remarkable improvements across US models in ENSO and PDO teleconnections (Fig. 1), the MJO, and the QBO (in high-top models).
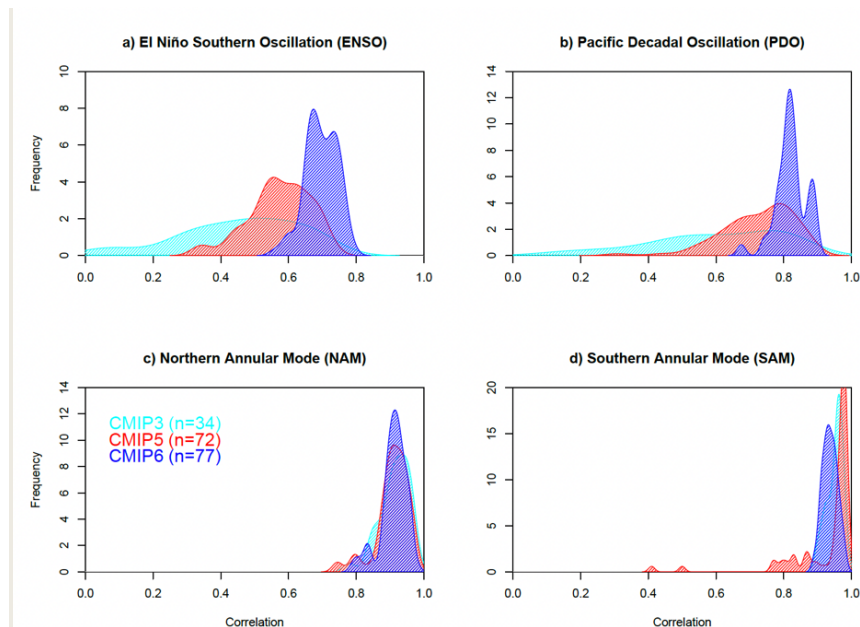
Figure 1: Changes in skill in the US models from CMIP3 (light blue) to CMIP5 (red) to CMIP6 (blue). Correlations of surface temperature patterns associated with a) ENSO, b) PDO, c) NAM and d) SAM). (Orbe et al., 2020).

Another study (and publication), led by John Dunne, focused on efficient ways to estimate Equilibrium Climate Sensitivity (ECS) in the US CMIP models and quantified the biases associated with currently used methodologies (Dunne et al., 2020). They found that ECS could vary by as much as 1ºC depending on method, and that pentadal analysis of years 51-150 reduces bias against long, coupled simulations.

Progress was reported on a "world-avoided" mini-MIP to look at the impacts that the Clean Air Acts have had on air quality and climate. This project, led by Jean-François Lamarque (NCAR), has developed appropriate emission scenarios (which are a variant of the CMIP6 historical emissions, and were created by S. Smith, PNNL) and has completed the first stage of the simulations with the participating groups. The analysis and write-up of these results is ongoing.

Finally, Ruby Leung summarized the ongoing seminar series for IGIM on Artificial Intelligence and Machine Learning approaches in climate modeling, pointing to some very promising work – as well as challenges – with these tools in the field.

GM-CAR Webinars and Workshop

The GM-CAR workshop was held virtually over four sessions in April 2020. Details of the presentations and links to the content are listed in appendix A. The topic of the workshop had been chosen at the close of the 5th USCMS in 2019, due to the increasing interest in understanding the widening of the spread in ECS across CMIP6 models and the indications that this was related to the updated treatments of cloud and aerosol microphysics. The virtual format allowed for an increased participation from a widely dispersed group of experts and an in-depth discussion of the presentations and issues. Participants ranged from 55 to 90 online viewers across the four sessions.
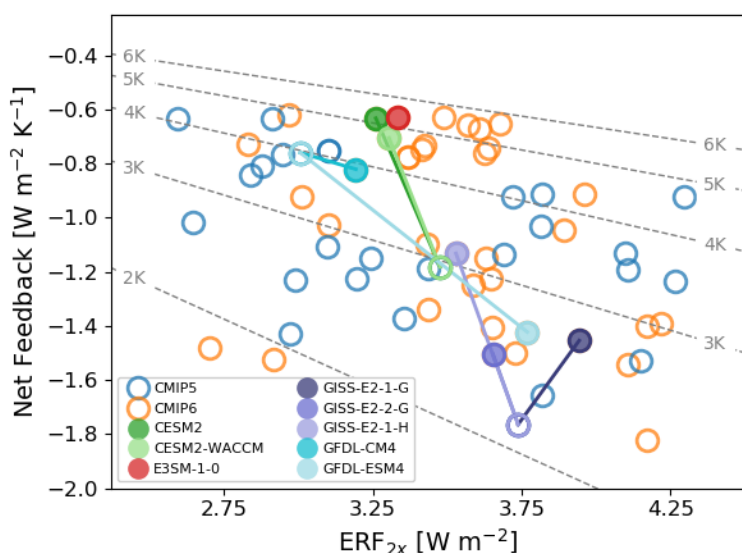

Figure 2. Forcing from $2xCO_2$ plotted against net feedback (proportional to the inverse of ECS) in CMIP5 and CMIP6 models, showing that the US models span the range of modeled ECS, but there is no consistent pattern of change from CMIP5 to CMIP6. Dotted lines are lines of constant ECS. (figure courtesy of Mark Zelinka).

The workshop was split into three themes: What is the current understanding of the spread in ECS in CMIP6 models? What is our understanding of observational constraints? What do analyses from the each modeling center show?

The motivating results (seen in Fig. 2) show that the increased spread in ECS in CMIP6 is driven by variations in both the forcing associated with doubling of CO_2 and the changes in feedbacks. The trajectories for the four US groups that have submitted to CMIP6 are varied, sensitivities have increased for NCAR, DOE and GISS models, but not for GFDL. Other analyses presented in the workshop looked at cloud processes, aerosol-cloud interactions, the spatial pattern of sea surface temperatures and potential constraints from observations. There was a robust result across groups that microphysical process changes impacted both the ECS (via cloud feedbacks) and the net forcing from aerosols over the 20th C. Multi-model studies by Zelinka et al. (2019) and updates as presented at the workshop as well as a summary given about the WCRP assessment on climate sensitivity (Sherwood et al., 2020) by Klein, point to low cloud feedbacks in the models as the main driver of the spread in ECS. One key question that resulted from the multi model studies was: Why has the extratropical low cloud feedback increased in CMIP6? A question we will further investigate in a collaborative multi center investigation.

The discussion about observational constraints regarding aerosol-cloud and cloud feedback processes, pointed to our limited understanding of the chemical composition of sea spray and its impact on cloud processes in the Southern oceans. Mixed-phase cloud processes and the role of ice nucleating particles (INP), thermo-dynamical phase shifts as well as satellite constraint model analysis studies regarding warm rain process where discussed.

The workshop shed light on many processes and feedbacks in our climate system that lead to our still limited understanding of ECS. Climate modeling centers have started large experiments of perturbed physics experiments (PPE) to systematically investigate different cloud feedbacks in the models. First results point to different findings concerning aerosol cloud interactions in the climate models and additional simulations including Large Eddy Simulations (LES) and Cloud Resolving Models (CRM) have been called for to advance understanding of cloud feedbacks and possible aerosol effects.
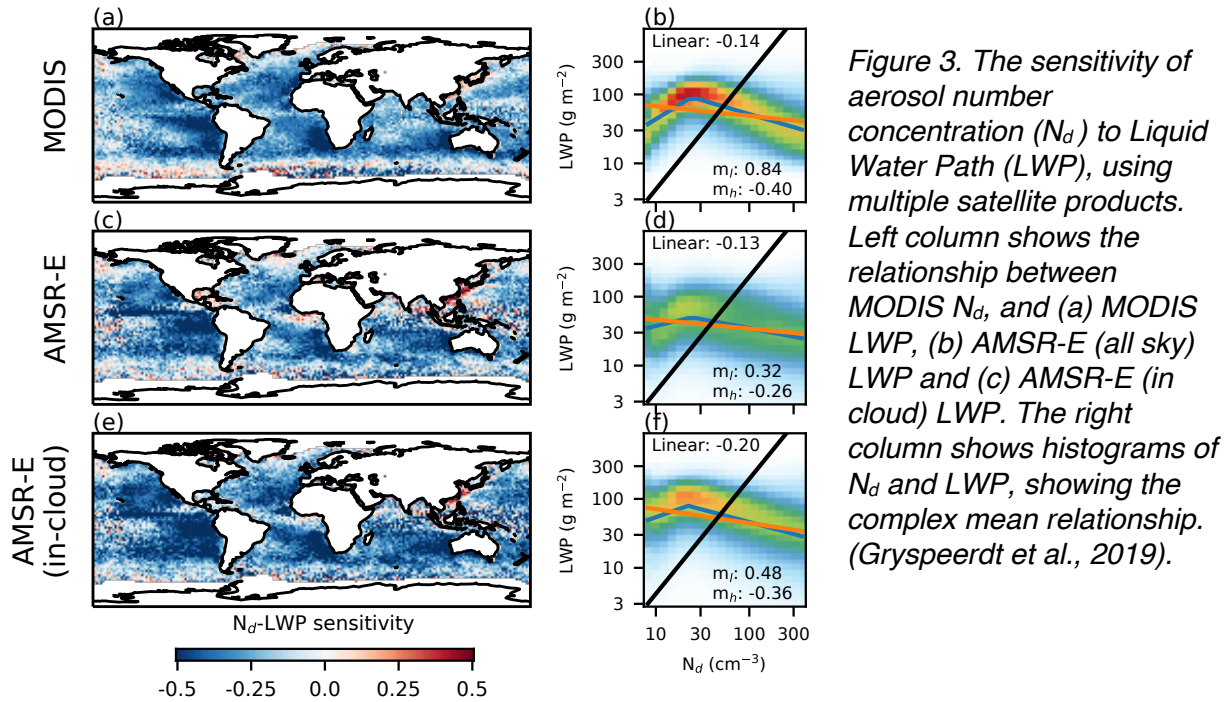

Figure 3. The sensitivity of aerosol number concentration (N_d) to Liquid Water Path (LWP), using multiple satellite products. Left column shows the relationship between MODIS N_d, and (a) MODIS LWP, (b) AMSR-E (all sky) LWP and (c) AMSR-E (in cloud) LWP. The right column shows histograms of N_d and LWP, showing the complex mean relationship. (Gryspeerdt et al., 2019).

As a next step for a joint USCMS activity we are proposing a very focused investigation, that can deliver results within one year, of constraining the aerosol influence on cloud liquid water path in all USCMS models. Previous modelling and observational studies have shown that multiple processes play a role in determining the LWP response to aerosol perturbations, but that the aerosol effect can be difficult to isolate. Models so far give very different answers regarding their N_d–LWP relationship, with most models showing a positive relationship throughout the entire N_d spectrum. However, satellite studies by Gryspeerdt et al (2019) show that the N_d–LWP relationship is negative in the majority of regions (Fig. 3), suggesting that aerosol-induced LWP reductions could offset a significant fraction of the instantaneous radiative forcing from aerosol–cloud interactions (RF_{aci}).

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In our proposed collaborative investigation, we want to take advantage of this satellite observed effects and test the sensitivity in the models towards this ACI defining quantity. Model simulations will be short, around one modelled year, so that all modeling centers can participate. Possibly single column model (SCM) might be included to look at top of the cloud entrainment processes and how this is resolved by the individual models. Natural experiments, such as volcanic eruptions, or anthropogenic effects such as ship tracks and industrial plumes can be utilized as sensitivity experiments for this investigation. A full proposal describing the experiments and anticipated analysis will be submitted to the program managers shortly.

6th USCMS 2020

The 6th USCMS was held virtually over two half days (June 30-July 1, 2020) (the agenda and link to presentations are given below as Appendix B). The first day was devoted to updates from the Centers on their progress and plans relevant to the IGIM. In addition, there was a touching tribute to Bill Lapenta, who passed in 2019 and who had been a major participant in previous USCMS meetings. The second day consisted of status reports on prior year activities, related community activities and discussion of future projects and preparation for next year's summit.

All centers discussed their plans for model enhancements including broader functionality (including fire, land-ice, and biogeochemistry), larger ensembles, higher resolution (globally and regionally), higher model top versions and component upgrades. The updates from GFDL, GISS, NCAR and DOE had a special focus on recent contributions to CMIP6 showing increases in model skill and discussing the factors involved in matching the historical temperatures in hindcasts (see Fig. 4). GMAO discussed their new capabilities to produce, an ocean reanalysis based on MERRA-2 (M2-Ocean) along with an upgrade in the seasonal forecasting system, a specialized atmospheric reanalysis for the 2000s that focuses on NASA's EOS and post-EOS observations, and, as the JCSDA-developed JEDI assimilation system matures by 2024, a coupled climate reanalysis (MERRA-3).

NCEP discussed the new Unified Forecast System (UFS), a community-based modeling system being developed to provide a common framework for all their operational forecasting systems. This will include an improved coupled Seasonal-to-Subseasonal (UFS-S2S) effort, aimed at delivering accurate predictions for time scales from weeks to months. Preliminary results with the new system (UFS p4) show a 5-7 day increase in the lead time for skillful Madden Julian Oscillation forecasts, and an estimated 1.5-fold increase in anomaly correlation scores for surface temperature at weeks 3 and 4 over the continental United States when compared to the currently operational model (Fig. 5).
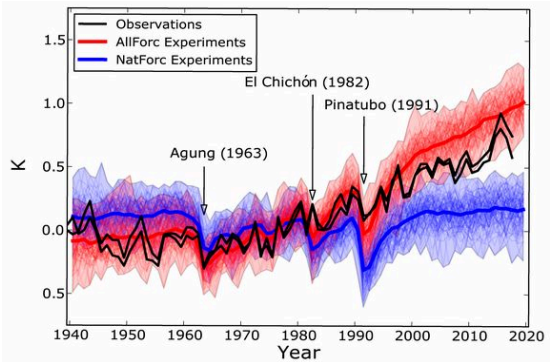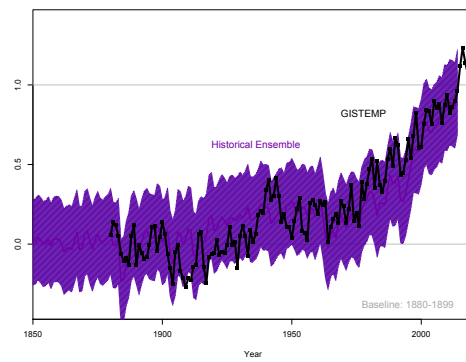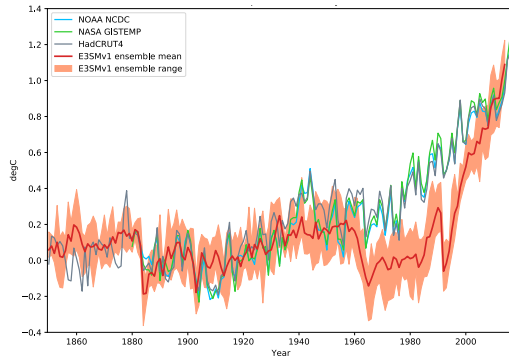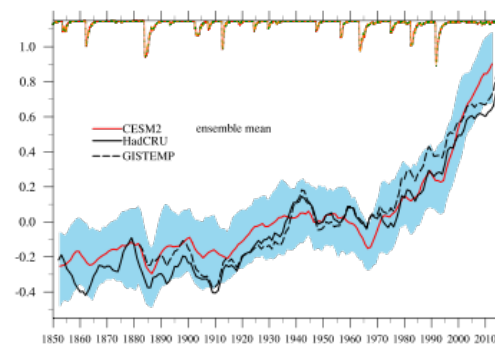
Figure 4. Historical simulations (hindcasts) from CMIP6 experiments from four US modeling centers.
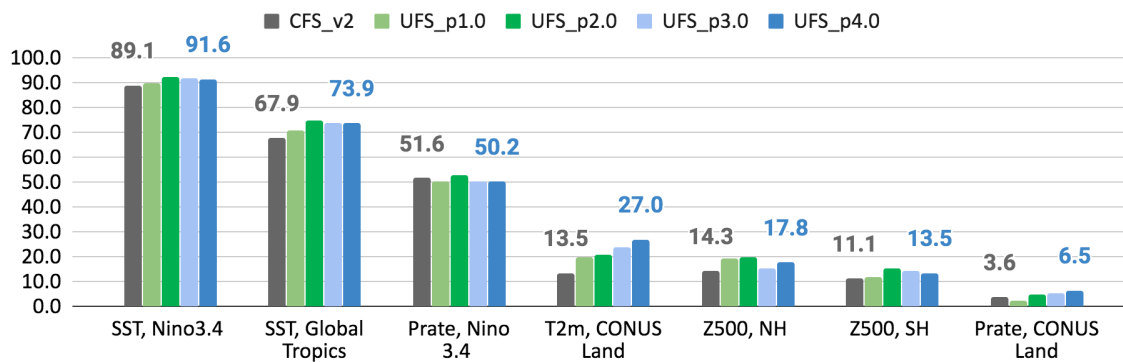

Figure 5: The anomaly correlation skill for weeks 3 and 4 forecasts for the same time periods from four consecutive prototypes of the UFS S2S system (colored bars) in comparison to the currently operational CFS v2 (grey bars) for different variables and regions.

The summit discussed prior year activities (as described above), and heard from USGCRP and OSTP about relevant initiatives being undertaken, namely the cross-agency organization for the 5th National Climate Assessment (due in 2023) and a new Fast Track Action Committee on Earth System Predictability being led by OSTP in which many USCMS participants are actively engaged.

Participants had multiple discussions sessions for collaborative efforts in the coming year. Notably, they gave in depth views on the current CMIP6 process and how this might develop in the future, possibly but not certainly, participating in a 'CMIP7' process. Collaborative project proposals that were discussed involved the continuation of the "World avoided" mini-MIP mentioned above, a new initiative on comparing liquid water and cloud condensation nuclei processes in the models (arising out of the GM-CAR workshop discussions), and exploration of coordinated COVID19-related emission reduction impacts on air quality and climate.

Plans for 7th USCMS (2021)

For the 2021 meeting (the 7th USCMS), the group agreed that Susanne Bauer (NASA) and Gokhan Danabasoglu (NCAR) would co-chair the meeting and coordinate with IGIM for the logistics. The meeting is scheduled to be held in the Washington, DC, area in the April-May timeframe, but as with all plans at the moment, the team will be prepared for all eventualities. A number of potential themes were discussed for the corresponding topical workshop, and the topic that was most favored was a focus on predictability in line with the OSTP initiative mentioned above. Ruby Leung and Dave Bader (DOE) suggested a focus on water cycle for the 2022 meeting and offered to organize that meeting.

Summary

In summary, the summit continues to provide a unique opportunity to deepen our collective understanding of changes in the emergent properties of the models, share plans and challenges among the groups and collectively (and productively) work on common projects of interest. The results coming out from this effort are more complex and interesting with each passing year.

Gavin Schmidt   (NASA GISS, 6th USCMS Chair)
Susanne Bauer   (NASA GISS, 6th USCMS co-Chair)

Appendix A: Agenda for the GM-CAR Workshop

Building from the detailed analysis of the last generation of models and the latest data from satellites (notably CloudSAT/CALIPSO), recent global model developments have focused strongly on improving cloud-aerosol microphysics and other moist processes. While greater skill in matching observed climatologies and variability are universal, there has been a significant divergence of climate model sensitivities in the latest model versions, beyond the assessed range of likely values. Initial analyses suggest that both cloud feedbacks in the Southern Oceans, and aerosol treatments including indirect effects, as large sources of this divergence. This workshop will examine the reasons for these divergences, commonalities and differences in parameterizations, process-based evaluation of the model outputs, and future research needs. The workshop consisted of 4 virtual sessions taking place over 4 weeks in April 2020.

Session 1: April 2nd, 2020: Climate Feedbacks and Equilibrium Climate Sensitivity.
Mark Zelinka (LLNL): Causes of high climate sensitivity in CMIP6 models
Andrew Gettelman (NCAR) Processes governing forcings and feedbacks.
Stephen Klein (LLNL): Climate Feedbacks in the WCRP Assessment on Climate Sensitivity

Session 2: April 9, 2020: Emerging constraints for aerosol – cloud interac8ons and cloud feedbacks
Johannes Mülmenstädt (PNNL) Can observations constrain parameterized processes?
Susannah Burrows (PNNL): Modelling and evaluating marine contributions to CCN and INP over the S. Ocn.
Ivy Tan (UMBC/GSFC): Physical Mechanisms Behind the Extratropical Cloud Optical Depth Feedback

Session 3: April 16, 2020: Part 1 Aerosol – Cloud Interactions in State of the Art Climate Models
Yi Ming (GFDL): A holistic approach toward modeling & understanding aerosol-cloud interactions
Po-Lun Ma (PNNL): Better cloud calibration leads to improved realism in global atmospheric simulation

Session 4: April 23, 2020: Part 2 Aerosol – Cloud Interactions in State of the Art Climate Models
Hailong Wang(PNNL): New aerosol treatments in E3SM and their impact on clouds
Andy Ackerman and Greg Elsaesser (GISS): Diversity of aerosol and cloud forcings in modelE3
Donifan Barahona (GMAO): Seasonal Predictions

Location for all presentations:
https://www.dropbox.com/sh/3lx5k8phiiiu70i/AAAkU6VGFAGi6W-OpM88HOV7a?dl=0

Appendix B: USCMS 2020 agenda

June 30

1:00 pm Introductions (Gavin Schmidt)
1:15 pm Charge for the USCMS (Gary Geernaert/Gavin Schmidt)
1:30 pm *Tribute for Bill Lapenta* (Dorothy Koch)

Model group updates (20 minutes per center)
   •   What is new since last year in science, priorities, challenges (including a description of the CMIP6 experience)
   •   Highlights of USGCRP priority-relevant current activities

1:45 pm E3SM (Ruby Leung)
2:05 pm GFDL (V. Ramaswamy)
2:25 pm GISS (Gavin Schmidt)
2:45 pm GMAO (Steve Pawson/Andrea Molod/Bill Putman)
3:05 pm NCAR (Gokhan Danabasoglu)
3:25 pm NCEP (Vijay Tallapragarda)

3:45 - 4:00PM Break

4:00 - 5:00 pm Summary of last CMS outcomes
   •   Modes of Variability in US climate models (Clara Orbe will summarize paper)
   •   Climate Sensitivity estimates (John Dunne will summarize paper)
   •   "World-avoided" mini-MIP (Jean-François Lamarque will provide status)

July 1

1:05 pm AI/ML lecture series (Ruby Leung will summarize talks)
1:25 pm Summary of GM-CAR workshop and next steps (Susanne Bauer)
1:50 pm Community-related activities
   •   NCA5 (Mike Kuperberg)
   •   Earth System Predictability – An OSTP priority (Annarita Mariotti)
2:35 pm Beyond CMIP6? (discussion led by Jean-François Lamarque)
3:00 pm Break
3:15 pm Continued discussion on CMIP6
3:30 pm Discussion/Action items for coming year incl. next year's theme and co-chairs
5:00 pm Close

Location of all presentations:
https://drive.google.com/drive/folders/1B_0HkjXPuNWOUtXrAQ8f-vzteD-6wYVu

Appendix C: Modeling Center representatives

The following lists representatives from the six centers for the 6th USCMS.

- Brian Gross   (NWS/NCEP) brian.gross@noaa.gov
- Vijay Tallapragada   (NWS/EMC) Vijay.Tallapragada@noaa.gov
- V. Ramaswamy   (GFDL)   v.ramaswamy@noaa.gov
- John Dunne   (GFDL)   john.dunne@noaa.gov
- Gavin Schmidt (Chair)   (GISS)   gavin.a.schmidt@nasa.gov
- Susanne Bauer (co-Chair) (GISS)   Susanne.e.bauer@nasa.gov
- Jean-Francois Lamarque   (CESM)   lamar@ucar.edu
- Gokhan Danabasoglu   (CESM)   gokhan@ucar.edu
- David Bader   (ES3M)   bader2@llnl.gov
- Ruby Leung   (ES3M)   ruby.leung@pnnl.gov
- Steven Pawson   (GMAO)   steven.pawson-1@nasa.gov
- Andrea Molod   (GMAO)   Andrea.Molod@nasa.gov
- Bill Putman   (GMAO)   William.M.Putman@nasa.gov